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## **The Role of Operations Research and Analysis in Concept-led Long-Range Planning**

Tony Brown and Tony Hibberd

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# The Role of Operations Research and Analysis in Concept-led Long-Range Planning

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DSTO-CR-0282

## **ABSTRACT**

Head Policy, Guidance and Analysis (HPGA) seeks to develop a strategic planning framework to better support Defence decision-making. This paper was written in response to HPGA's request for advice on the potential role of Operations Research (OR) and analysis in such a framework. A broad interpretation of OR is proposed that includes qualitative analysis of problems that are not amenable to the quantitative methods with which OR is more traditionally associated. Cultural and ownership issues that must be addressed if OR is to be successfully incorporated into Defence's decision-making processes are discussed. It is argued that OR and analysis should be conducted with a decision perspective, and that analysis should be embedded in all aspects of a strategic planning framework. Working definitions of terms and concepts are presented to provide a common lexicon for those involved in the development of long-range planning.

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# The Role of Operations Research and Analysis in Concept-led Long-Range Planning

## Executive Summary

Head Policy, Guidance and Analysis (HPGA) and Director-General Military Strategy (DGMS) seek to build a strategic planning framework that will provide improved decision support for senior Defence committees and decision-makers. This paper has been written in response to their request for advice on the potential role of Operations Research (OR) and analysis in this framework.

OR is "the application of the methods of science to complex problems involving human and technical factors, with the aim of improving decisions"<sup>1</sup>. A broad interpretation of OR is proposed to include *qualitative* analysis of problems that are not amenable to the quantitative methods with which OR is more traditionally associated. With this interpretation, OR is considered as a rigorous and structured approach to providing decision support, where the nature of the analysis, the tools used and the characteristics of the answers are dependent on the type of problem to be addressed. For a concept-led long-range planning framework many of the problems to be addressed are not likely to be amenable to quantitative analysis, but can be addressed rigorously with qualitative analysis. In contrast, resource decisions to be made by senior committees are more likely to require quantitative analysis. In either case, the broader interpretation of OR can provide value by bringing rigour to the development of decision support information.

The incorporation of OR and analysis into the long-range planning process raises ownership and cultural issues. These issues are various, depending upon how OR is incorporated into the organisation. Of particular significance are: the degree to which objective and impartial analysis is desired by the organisation, the arrangements for maintaining an analytical capability and the degree to which the organisational culture allows open and robust debate.

The argument is made that OR can provide the greatest contribution to the long-range planning framework if a decision perspective is adopted. That is, analysis is performed with explicit links to actual or potential decisions. In practice, this means that analysis is focussed on providing decision support information of direct relevance to decision-makers, rather than simply for purposes of discovery. Embedding analysis in all parts of the long-range planning process will assist in achieving that aim.

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<sup>1</sup> Agrell, P.S. "Operational Research at the National Defence Research Institute of Sweden", Omega, Vol 13 No. 2, p 121-124 1985

## **Contents**

<b>1. INTRODUCTION.....</b>	<b>1</b>
<b>2. DEFINITIONS .....</b>	<b>1</b>
<b>3. WHAT IS OPERATIONS RESEARCH? .....</b>	<b>3</b>
<b>4. ORGANISATIONAL IMPLICATIONS OF OPERATIONS RESEARCH.....</b>	<b>7</b>
<b>5. INTEGRATING ANALYSIS INTO CONCEPT-LED LONG-RANGE PLANNING.....</b>	<b>12</b>
<b>6. CONCLUSIONS.....</b>	<b>15</b>
<b>7. REFERENCES .....</b>	<b>17</b>

## 1. Introduction

1. Head Policy, Guidance and Analysis (HPGA) and Director-General Military Strategy (DGMS) seek to build a strategic planning framework that will provide improved decision support for senior Defence committees and decision-makers. Specifically, the focus is on producing a concept-led long-range planning process. HPGA's view is that the framework will build on extant activities and experience as far as possible. It may be necessary to optimise existing elements of the framework and their interrelationships, and to implement and develop elements that do not currently exist.
2. The ambitious nature of this undertaking, together with the fact that there is not a "clean slate" to work with, means that HPGA/DGMS need to drive the development and implementation of the framework hard and fast to ensure that it has sufficient momentum and progress to survive beyond the current posting cycle. They have requested DSTO to provide information to help focus PGA, DSTO, Services and private sector effort in developing and implementing the framework.
3. This information/discussion paper is provided in response to a request from HPGA/DGMS for advice on the potential role of operations research and analysis in a long-range planning process.
4. **Scope.** This paper presents a discussion of what is meant by the term "Operations Research", how it could contribute to long-range planning in Defence, some organisational implications of operations research and how it might be integrated into a concept-led long-range planning framework. The paper also presents definitions of terms and concepts that are intended to provide a common lexicon for those involved in the development of long-range planning.
5. **Aim.** The aim of this paper is to provide HPGA and DGMS with information and discussion that will inform their decisions on the potential role of operations research and analysis in the development and implementation of a framework for concept-led long-range planning in Defence.

## 2. Definitions

6. **Operations Research (OR):** "*the application of the methods of science to complex problems involving human and technical factors, with the aim of improving decisions*"<sup>1</sup>.
7. OR had its origins in analysing military operations at the tactical level during the Second World War. It has since been applied beyond the military sphere to include the private and civilian public sectors, and in the realm of strategic decision-making. Distinctions are often made between the terms Operations Research, Operations Analysis, Operational Analysis, Operational Research, System Analysis, and Management Science,

but these are somewhat academic, and for the purposes of this paper they are taken to be interchangeable.

8. **Scientific Method:** "*the process of reasoning—using methods of induction, deduction and intuition informed through observation and experience—to formulate, test, analyse and review hypotheses (and/or posited explanations) about the nature of the world in order to generate understanding*".<sup>2</sup>

9. Further discussion of the scientific method is given later in the text.

10. **Decision:** "*a determination arrived at after consideration of several possibilities*".<sup>3</sup>

11. In the Defence context, the term "decision" often refers to specific senior committee considerations such as those that occur at well-defined points during the acquisition of a new capability. In the context of Defence long-range planning, and for the purposes of this paper, the term will be taken to have a wider meaning to include potential decisions that are not yet on any current decision schedule.

12. **Defence Long-range Planning:** "*a process that investigates possible future operating environments and produces a strategy to best fit the Defence organisation to those environments, given a host of constraints, including financial ones*".<sup>4</sup>

13. The timeframe encompassed by the phrase "long-range" is not precisely defined, but is related to how long it takes to make changes in the system and the length of time those changes will have effects on the system. It will be different for each sector of Defence, depending, for example, on how long it takes to make changes to organisational structures or to bring new platforms into service, or the expected service life of a given platform. In the Defence context this might typically be a 10-30 year horizon. Defence long-range planning will usually include considerations of the context within which the plan will operate, concepts that inform possible ways for the organisation to operate now and into the future and the capability implications of the context and concepts.

14. **Hypothesis:** "*supposition made as a basis for reasoning, without assumption of its truth, or as a starting point for further investigation from known facts*".<sup>5</sup>

15. In the present context, "hypothesis" includes suppositions that are appropriate for discovery and exploration, not just those that can be used for statistical interpretation of "hard" (quantitative) experiments. It also includes the idea of "*layered hypotheses*", in which subordinate hypotheses of increasing detail or focus are proposed so that experiments can be designed to examine several aspects of a problem.

16. **Experiment:** "*procedure adopted to test hypothesis or demonstrate known fact*".<sup>6</sup>

17. The design of experiments (the nature of the methodology adopted and the experimental tools used) should be guided by the nature of the hypothesis or questions to

be addressed. Experiments may be conducted using back-of-the-envelope calculations, computer models, simulations, seminar games, campaign models, wargames or any number of other experimental tools. The essential point is that the hypothesis should drive experimental design, not the other way around.

18. **Analysis:** "*separation of a whole, whether a material substance or any matter of thought, into its constituent elements as a method of studying the nature of a thing or of determining its essential features*".<sup>7</sup>

19. "Analysis" in this context is any activity that contributes to the understanding of a system. The dominant paradigm in Defence appears to be that analysis is a separate activity that occurs after an experiment is conducted. This paper takes the view that analysis should be embedded throughout the concept-led long-range planning process, and that one of its major functions is to guide experimentation.

20. **Model:** "*simplified description of any system etc. to assist calculations and predictions*".<sup>8</sup>

21. Models are frequently misunderstood to embody some truth or reality about the system they describe. They should be regarded as a representation of the phenomenon being studied that is adequate for the purpose of the study. While some models may be expressed in a mathematical form, many are non-mathematical.

### 3. What is Operations Research?

22. A more expansive description of OR is:

*"a systematic approach to helping a decision maker choose a course of action by investigating his full problem, searching out objectives and alternatives, and comparing them in the light of their consequences, using an appropriate framework ... to bring expert judgment and intuition to bear on the problem. This suggests that a cycle consisting of definition of objectives, exploration and evaluation of alternatives in terms of their costs and effectiveness needs to be considered. The cycle may be repeated in the light of new information required while redefining the objectives and identification and evaluation of alternatives, till the total spectrum is completely understood."<sup>9</sup>*

This is an application to the decision-making process of the scientific method used by scientists to investigate natural phenomena.

23. The scientific method<sup>10</sup> starts by performing an analysis of the system under examination. This means that the system is split into manageable parts that can be observed and investigated independently. These observations underpin the formulation of a model that explains the system's behaviour. This model is then tested via experiment for agreement with the facts, and adjusted as necessary. This cycle continues, in an attempt to eventually completely explain the behaviour of the system. It is important to note that the

model is constantly re-evaluated against observations made, and if found lacking, is modified. A model should be viewed as a dynamic item within the experimental process.

24. An aspect of the culture of science is the principle of openness. "The method and tradition of science require that results be openly arrived at, so that any other scientist can retrace the same steps, and get the same results".<sup>11</sup> This openness allows science to be self-regulating, in the sense that all scientific work should be peer reviewed, so that assumptions and methodology can be discussed. The open publication of scientific work aids in achieving the goal of objectivity, where questions of the validity of results can be raised by anyone, regardless of their relative position or standing. This leads to the creation of an atmosphere where robust debates can be had about the solution to problems. The nature of scientific debate is such that potential solutions to problems are discussed objectively and without prejudice, meaning for example that novel, innovative and "out of the box" solutions can be debated, and not dismissed out of hand.

25. How can this analytical cycle and culture be applied to assist decision-makers in long-range Defence planning? Firstly, the reason or reasons for a decision needing to be made are analysed. For example, a decision of whether or not to adopt the concept of Network Enabled Operations (NEO) would be driven by the possibility that it is a better way of performing combat than the currently used concepts. This statement of a decision's "trigger" puts the decision into context, and helps direct the subsequent analysis. In the NEO example, the analysis would be directed towards defining exactly what "better" might mean, and how it can be measured.

26. Furthermore, decisions made in long-range planning will by definition have long-term effects, and will subsequently have consequences for other parts of an organisation. Therefore the decision needs to be examined within the system of which it is a part. This brings to light all of the factors that need to be analysed, and brought to the attention of the decision-maker. As OR endeavours to investigate systems and understand the way they operate, the scientific process does add great value and clarity at this stage.

27. Once the nature and scope of the decision have been clearly defined, the key arguments relevant to the decision can be developed. This allows the step of performing research and collecting data to begin. The value that OR can bring at this point is the rigorous and unbiased fashion in which data can be collected. The scientifically minded investigator should be able to find and evaluate data independently of current wisdom. Depending on the decision to be supported, these data may range from performance specifications at the "hard" OR end of the spectrum, all the way through to collecting expert opinion at the "soft" OR end. "Hard" and "soft" OR refer to quantitative and qualitative OR, respectively. The nature of the decision will also determine the granularity of data required.

28. After the data have been collected and analysed, hypotheses regarding the factors that will affect the decision can begin to be formed. This stage is intellectually equivalent to the forming of a model in the cycle of scientific investigation. In some cases it is appropriate to

build hard mathematical models of the system, and use the model to investigate the effects of potential changes. This generally works quite well for operational questions, such as the best way to organise logistics. The questions that arise in higher-level strategic decisions may not be so amenable to mathematical modelling. Questions at this level typically contain "soft" issues, such as a high level of behavioural content for which there is little theory. There also may simply not be enough facts about the problem to produce a good mathematical model. Both of these situations could apply to the problems considered by long-range planners.

29. OR deals with this situation by using tools that are appropriate to the task. The approach is still to formulate a representation or model of the question under consideration but this model may be expressed in the form of an influence diagram, rather than mathematics. What is common to both the "hard" mathematical and the "soft" models is that, whatever tools and techniques are used to build and articulate them, they will be developed following a scientifically sound procedure.

30. Models developed in a scientifically sound fashion are built upon a set of hypotheses. Hypotheses must be formulated in such a way that they are *testable* by experiment. It is important to note that no hypothesis can be proven true, but they *can* be proven false. In practice, this means that the results of an experiment can provide support for a hypothesis but not proof of its correctness. As soon as experimental evidence is found that contradicts the hypothesis, a new hypothesis must be formulated that is consistent with the new results *whilst still being consistent with all previous observations*.

31. The way an experiment is run should be determined by the hypothesis that needs testing, and the level of detail that is required. Hypotheses flow from investigation into a particular question, and the level of detail required will depend on the decision to be supported. Therefore, it is important that any experimentation activity have a clear purpose, in the form of a decision that it will support or knowledge that it will seek to discover. It is possible to engage in undirected activities in the hope that some interesting information will appear, but this is usually an inefficient and wasteful use of resources that has a low chance of success. Having a decision to inform also means that relevant metrics or measures of performance can be proposed, and it will be clear where the information gained from the experiment is to be used.

32. Experimental design should be done in a fashion that allows the actual hypothesis to be tested independently of other factors. For example, a seminar wargame to test a new concept introduces extra variables, such as the concrete force structure to be used for the purposes of the game, and the judgments of the players. The experimental procedure should ideally include a method for factoring out these variables, so that only the value of the concept is tested. Doing this may require the application of several experimental techniques, rather than being limited to one. Because a good scientific methodology keeps track of any extra variables introduced into an experiment, it is valuable to have an OR analyst involved in the experimental design.

33. Producing a good and robust experimental procedure does not happen by magic. Prior to an experiment being performed, a quantity of analysis must be done to guide and inform the subsequent experimentation. This analysis, which might be referred to as *pre-experimental analysis*, should concern itself with several issues. Firstly, it should take a system perspective, articulating all of the factors that will influence the decision. This provides a clear statement of what the research and experimentation should set out to achieve, and provides the link between experimentation and the decision. Secondly, a hypothesis needs to be expressed in a form that can be tested. Formulating a hypothesis requires analysis of the information understood prior to an experiment being run. This hypothesis may contain many assumptions and unknowns, but without a hypothesis, no meaningful experiments can be performed. The final piece of analysis involves the definition of metrics or measures of performance. These should be related to the hypothesis under consideration in an experiment, and the drivers of the decision. Performing this pre-experimental analysis is vital to informing experimental design.

34. At the end of a set of experiments, the *post-experimental analysis* should lead to the hypotheses under consideration being adjusted to account for the observations that arise, and to inform subsequent experimentation. The cycle of analysis, experimentation and revising hypotheses can, in principle, continue indefinitely. However, at some point the conclusions of the research and experimentation will be presented. Due to time and resource constraints, all of the hypotheses made might not have been tested. In addition, there will always be factors and variables that cannot be measured completely. Thus any results will contain some level of uncertainty, whether that be in the form of assumptions, expert opinions, or the like. A well structured OR study will keep track of these uncertainties and present them along with the conclusions, by providing some comment on the level of confidence of the results. A good study will also perform a sensitivity analysis, which asks the question: how much do my conclusions change if some variables in the model were to change?

35. Including this last step is vital as it expresses the level of risk in a given decision. For a decision-maker, a part of risk involved in pursuing a given option is related to what is unknown. The conclusions of an OR study should include the pros and cons, as well as the level of risk associated with each. These factors can then be evaluated by the judgment of the decision-maker. Note that OR does not remove the need for judgment in a decision, but it should provide the decision-maker with a more robust appreciation of the drivers of the decision, and a greater understanding of the advantages and risks associated with a given course of action. This understanding allows the decision-makers to have a robust debate regarding the options based on as much fact as possible, rather than relying solely on judgments.

## 4. Organisational Implications of Operations Research

**36. Decision-making Culture.** The desirability of a structured and rigorous approach to decision-making is self-evident to most OR practitioners and strong arguments from a practitioner's perspective can be mounted to support this position. However, it is by no means clear that senior decision-makers share this point of view. The recently-retired Vice Chief of the Defence Force, LTGEN Des Mueller, has expressed this in blunt terms:

*"You should therefore remind yourselves that decisions on major matters ... will be made at levels where intuitive judgement and not detailed analysis, with the possible exception of financial analysis, tends to prevail. The reality of this has precipitated deep despair in the heart of many an operations research analyst."*<sup>12</sup>

37. While this may be starkly expressed for effect, the history of quantitative OR support provided directly to senior decision-makers through the committee process<sup>1</sup> has not been encouraging for the OR community, and lends some weight to LTGEN Mueller's sentiment. Figure 1 illustrates the decline in the number of quantitative analysts providing such support to central Defence decision-makers that has occurred over the last twenty-odd years. Whether the decline has occurred because the quality or focus of the analyses were not appropriate, or that the results were at odds with political imperatives, or the decision-making environment was not suited to the use of analysis (or any number of other reasons) is not clear. This decline does seem to indicate that, over time, the decision-making culture of Defence has moved away from using analysis. OR is more likely to have a positive impact if this trend can be reversed.

38. OR could be incorporated into an organisation's decision-making processes in a number of ways and with a variety of expectations. Each of these have implications for the organisation (and for the OR analysts) that need to be understood and considered before implementing any particular OR regime. If the implementation is done well, it could help reverse the trend mentioned above.

39. **What is independent analysis?**<sup>13</sup> Because it is an application of the scientific method, OR should provide support to decision-makers that is *objective* and *impartial*. However, the related issue of *independent* analysis can have a significant impact on the ability of OR to provide useful support to decision-makers. There are several dimensions to independent

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<sup>1</sup> The data in Figure 1 refer to the number of analysts whose work was represented directly at committee by a two-star position. This was initially Controller Military Studies and Operational Analysis, then Controller, Projects and Analytical Studies, then Controller, External Relations, Projects and Analytical Studies, then FAS Force Development and Analysis, then Head Capability Plans and Resource Programming, then Head, Strategic Policy and Plans (in actuality, DEPSEC S) and finally FAS Capability Investment and Resources. Governance arrangements for the input of analytical advice from DSTO to the committee process are fundamentally different, as the accountability goes via the sponsor's desk officer. This is related to the gradual downgrading of DSTO's position on the relevant committee from "accountable for various inputs" to "advisory" only, and its general thrust as a support organisation.

analysis, each of which can lead to dysfunctional conditions for providing sound advice appropriate for the Defence organisation as a whole if they are not handled appropriately.

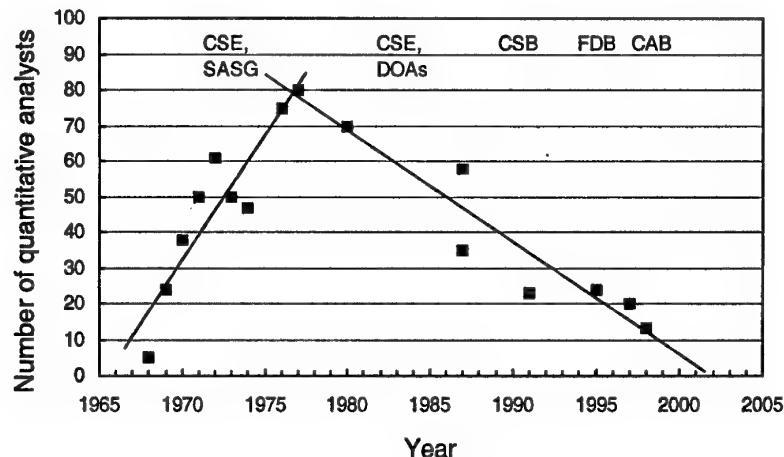


Figure 1: Number of analysts providing quantitative analytical support directly to central Defence decision-makers through the committee process as a function of time.<sup>14</sup> The organisational units that were responsible for providing quantitative analysis are indicated at the top of the graph. 1974-75 marks the period of the Tange reviews and the formation of the Department of Defence. Data for the years prior to 1974 refer to analysts in the Department of Supply.

40. Firstly, if the decision-makers consider the advice they get as irrelevant and only good for "cosmetic" purposes, the value of the advice is bound to be minimal. Under such circumstances the OR analysts could be said to be *too* independent, in that the decision-makers of the organisation do not see the advice to be of relevance to them. In this case the independence has become mutual and absolute, and is definitely counterproductive to generating favourable conditions for OR-based advice.

41. Secondly, generation of good advice requires free access to all relevant input data and critical assumptions, an ability to make sound judgements on their validity and appropriateness, and the freedom to exercise the analyst's best professional knowledge and judgement. This aspect of analytical independence implies an ability to formulate and assess the goals of the organisation, expressed in terms suitable for analytical purposes. Parts of an organisation that perceive that the results of an analytical approach may threaten their comfortable *status quo* may decline to provide information (or even provide misinformation) for analysis, and thereby undermine the validity or usefulness of the analysis. Another potential barrier to objectivity is that the requirements of a military command structure may hinder the open debating of hypotheses and results, with the possible result that potentially fruitful solutions might never be considered.

42. Thirdly, perhaps the most important factor to be considered is that of resource independence. In every organisation resources are limited and priorities must be made both between OR and all other activities in the organisation, and within the broad range of possible OR projects. The dysfunctional conditions that are of greatest concern here are those that can arise when the priorities for OR work are affected by the actual results of analyses and the content of advice given as a result. The most obvious example would be for the organisation to link future priorities of work to getting the "desired" results from present analyses, or to put it bluntly: buying the analysis needed to support *a priori* conclusions.

43. If OR is to support a planning framework it must be able to survive within the political environment of which it is a part. The nature of objective analysis means that at some point OR activities will undoubtedly create tension with other areas of Defence (it is not possible to please all of the people all of the time). In a large bureaucratic organisation such as Defence, this is guaranteed to generate political attacks on the OR group. If OR and analysis are to be incorporated as an essential part of a long-range planning framework there must be strategies in place to deal with these pressures.

44. **What is the value of independent analysis?**<sup>13</sup> If an organisation is to develop and improve to remain relevant and competitive as the world around it changes, it must have mechanisms in place that will allow it to innovate. It is vital that conventional wisdom is challenged and new concepts and radical solutions are raised and thoroughly discussed. Good OR can make significant contributions to these forces of potentially beneficial change within an organisation, by providing the forum for a robust, scientific debate of questions and their solutions. Enabling this debate would be useful for long-range planning, as it helps in the process of achieving cultural change by providing the means to escape the limits of accepted wisdom. In doing so, however, the advice provided by analysts is very often not wanted by those parts of the organisation that might be candidates for change: change can be difficult and uncomfortable. If the OR group is dependent on those elements of the organisation for the conduct of its analyses, or even for its continued existence, unwanted but relevant advice may be a rare deliverable.

45. The utility for the organisation as a whole of OR contributions to planning and decision-making hinges on arrangements that secure the production and delivery of all relevant results and advice, irrespective of the degree to which it is wanted by the organisational elements in question. This implies that the organisational culture is such that open and robust debate and questioning is not only acceptable but encouraged. It can pose a significant challenge to management to encourage such a culture to flourish if it is not already doing so, but without it the value of OR is unlikely to be realised. It should be noted that the propensity to repel certain types of advice is by no means a "constant of nature" in organisations. Indeed, it varies from one organisation to another, and also varies over time as a function of the internal "climate" of the organisation.

46. **Independent scrutiny vs doing the analysis.** Analysts can provide an independent review function within an organisation, essentially providing an assessment of the rigour

of a process and the conclusions that are drawn from it, or they can be an integral part of developing processes and conducting analyses. If analysts have provided advice, assisted in the development of processes and/or conducted analyses, it is not possible for them then to provide an assessment or review of the rigour of the work without a real or apparent conflict of interest. The organisation for which the analysts work must be very clear about what role the analysts are expected to play: "doers" or "reviewers", but not both. If both roles are required, the organisation should identify two distinct groups of analysts to perform the two functions.

**47. Impartial analysts or advocates?**<sup>15</sup> Ethical dilemmas can arise as a result of the manner in which OR analysts present the results of their work. Three general cases can be envisaged:

- the analyst presents the facts in an objective and unbiased manner and do not advocate any particular position;
- the analyst has a moral responsibility for the effects of his own involvement; and
- the analyst works openly as an advocate for a particular position.

**48.** As scientists, OR analysts usually find themselves in the first situation, presenting objective analyses and leaving it to the decision-maker to make their judgements. When working in policy areas, however, analysts often find themselves operating in the second of these regimes and because of the nature of the work must take great care that personal biases are not embedded or implied in the analysis. When the analyst works explicitly as an advocate, for example as an expert witness or adversary, he is guided principally by his personal code of ethics. There is no imperative to volunteer all the relevant information in this situation, only that which supports the position being advocated. The analyst needs to know whether he is employed as an impartial provider of analysis, or an advocate, or something in between. It is also important for both the analyst and the organisation for which he works to understand the potential pitfalls that may arise when the analyst is operating at any given point on this continuum.

**49. Tool development vs analysis.** Anecdotal evidence<sup>16</sup> suggests that there are approximately 200 OR practitioners currently employed by Defence, principally in DSTO. The majority of these are tool development oriented, providing support to projects, tactics development or training rather than engaged in providing analytical support for decision-makers. The question arises as to where to place the balance of the OR effort for long-term planning, into tool development for long-range planning, or into actually doing the analysis.

**50. Quantitative vs qualitative analysis.** In the preceding discussion it has been implicitly assumed that "hard" and "soft" (quantitative and qualitative, respectively) OR are of essentially equal value to the decision-making process. Whilst the characteristics of a structured scientific approach to both quantitative and qualitative analysis might be similar, the problems to which they are applied, the tools that might be used and the results that can be expected are not. Quantitative OR is more applicable in situations where models are predictive to a reasonable extent, while qualitative OR applies where

models are more exploratory in nature. Quantitative OR often results in numerical data that are useful for underpinning decisions about relatively concrete issues (the results of the EO Stockholding study are an example), while qualitative OR can provide clarity and insights into a problem but rarely provides numerical support for decisions (analysis of a future warfighting concept might be an example). The nature of the decisions to be supported will to some extent dictate which end of the analytical spectrum is appropriate.

51. Analysis should be conducted with rigour regardless of whether it is at the qualitative or quantitative end of the spectrum. However, rigour should not be confused with accuracy or precision. Accuracy relates to the degree to which results accord with reality, while precision refers to the definiteness with which an answer is given. An example of a precise and accurate model is one that makes numerical predictions that are in very close agreement with subsequent observations. It is entirely possible, however, to achieve accuracy without precision, and precision without accuracy. Qualitative analysis will almost certainly be less precise and less accurate than quantitative analysis. The critical point is that the nature of the analysis conducted to support a particular decision should, as far as possible, match the decision-maker's needs for accuracy and precision. Some decisions, for example, can be informed using qualitative analysis and don't require high degrees of certainty (eg. futures analysis) but the analysis should still be conducted with rigour.

52. The reality is that all forms of analysis will have some level of imprecision and inaccuracy involved, if for no other fact than models are just representations of the real world rather than reality itself. The way that this can be dealt with is by expressing some measure of the confidence of the conclusions or the outputs. In quantitative analysis, this can be done relatively easily, in the form of error bars or confidence intervals. For qualitative analysis this is somewhat more difficult. Qualitative methods such as wargaming represent complex systems usually involving human interaction, and running through a scenario just once is unlikely to provide an accurate answer. The way that qualitative and quantitative analysis can deal with uncertainty should have some influence over which types of analysis are used.

53. **What decisions are to be supported?** Senior committees and decision-makers have a legal obligation to make year zero resource decisions and to provide assurance that further year funding will be adequate to support the results of those decisions. In making these decisions, senior executives are responsible for ensuring that they are consistent with Government guidance and for presenting a range of options and recommending or proposing the most cost effective option in net present value terms for Government consideration. They are also not to mislead Government when providing assurance of further year funding to operate whatever is implemented. However, the in-year resource decisions appear to be accorded a higher priority and importance than the assurance of future affordability, possibly because subsequent decisions can address problems caused by previous assurances of affordability that turned out to be inaccurate.

54. Because long-range planning has a time horizon significantly beyond the immediate year zero resource decisions that the senior executives are focussed on, it can be difficult to engage them in such planning and for them to see immediate value in it. It is also possible that the analytical community has done a poor job of articulating the implications of long-term issues for decision-makers or of breaking down the uncertainty by exploring the future space systematically.

55. OR has the potential to add value to decision support when resource constraints are explicitly addressed in the analysis. It could do this through application of realistic resource constraints in the initial development of options or through some form of cost-effectiveness analysis of options, regardless of how those options were developed.

56. **How much OR is enough?** For OR to have relevance to decision-makers it must deliver results that could make a material difference to the decision in time to inform the decision. The academic 110% solution delivered 3 years after the decision is made is of no use, but an 80% solution delivered in reasonable time *may* offer useful decision support. This issue of delivering timely advice is crucial, because of the nature of Defence's decision-making process, which is influenced by the rapidly changing policy environment.

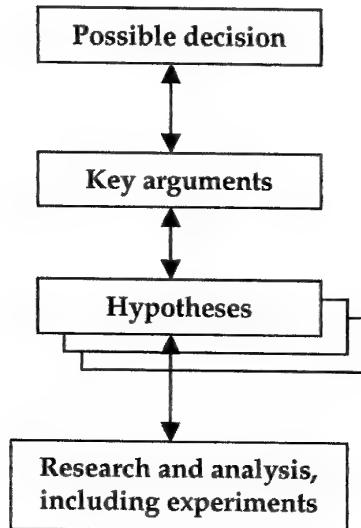
57. All decisions will involve both judgement and analysis. For senior executives the balance lies towards judgement, while for analysts the balance lies towards analysis. For senior executives to place more emphasis on the results of analysis in making their decisions the analysis will have to demonstrate its value. Perhaps the principal way it can do that is to provide them with objective and transparent decision support material to underpin and augment their judgements. This would provide a more readily auditable basis for decisions that could more readily be communicated with Government, which currently has little confidence in many of the decisions taken by Defence.

58. **Resources.** There are never enough resources to do everything. The cyclic nature of the scientific method means that not insignificant resources might be required to do OR well. Realistic choices must be made regarding the scope and scale of activities to be undertaken. The question to be answered here is where the best value can be obtained for the limited resources available for analysis.

## 5. Integrating Analysis into Concept-Led Long-Range Planning

59. The cultural and ownership issues discussed previously need to be dealt with if analysis is to be integrated into an organisation. The solutions to these problems will depend to a large extent on how analysis is incorporated into the planning framework (if at all) and what the organisation expects to gain from analysis. What we wish to present is a possible mindset regarding analysis and experimentation that will help guide its position in a planning framework. We also argue that this mindset will take steps to dealing with

some of the above cultural problems. The key element to this mindset is that the analysis should take a *decision* perspective (see Figure 2).



*Figure 2: A structured approach to analysis in support of decision-making.<sup>17</sup>*

60. The idea behind taking a decision perspective is that research and analysis should be directed towards possible decisions, rather than searching for knowledge generally. It should guide the analysis to provide the understanding that decision-makers need in terms of both breadth and depth, and explicitly discuss risk. Note that the framework indicates possible rather than actual decisions. The reason for this is that the lead-time to provide appropriate material for decision support may be lengthy, so analysis may need to pre-empt decisions. This approach will also support analysis for long-range planning, where the issues considered may have little immediate committee visibility. What an analytical procedure should do is imagine a possible decision that might arise, and refine its methodology to provide information relevant to the key arguments, that is, the factors affecting a decision.

61. The way this can be achieved is to make hypotheses regarding the key arguments, and use research and experimentation to test these hypotheses. For example, a decision on whether to adopt a new warfighting concept would be based on its relative effectiveness. The hypothesis to be tested would be that the new concept is more effective than those currently in use. A program of experimentation and analysis could then be developed to test this hypothesis. Because the hypothesis has been linked to a possible decision, the analysis and experimentation done should be useful to long-range planning. Allowing the culture of science to work here should also encourage robust debate to take place, which helps the development of new ideas, and hence good solutions to problems.

62. Because decision-makers should consider the implications of a decision for the entire organisation, analysis and experimentation linked to a decision should also take a *system* perspective. This simply means that analysis should take into account the whole system, from the strategic level, through to capability considerations if appropriate. There should also be considerations of the long-term effects of current decisions. Clearly the way a particular piece of analysis considers the system will depend on the decision. However, taking a system perspective has implications for the tools and techniques used. Ideally, a family of appropriate models, simulations and analytic methods could be developed and integrated, so that knowledge at different levels and from different perspectives could be readily used to give an overall description of the implications of a decision. This would require analytical tools to break a system down into manageable parts that can be studied more or less independently, tools to do exploratory analysis for breadth, tools to test high resolution hypotheses, and finally, integrative techniques to build up the entire picture.

63. One analytic method that could be used to break down problems into manageable pieces is to use the idea of layered hypotheses. For example, the NEO concept would involve measuring its effectiveness. The NEO concept is made up of several smaller building blocks, such as the ability to conduct secure communications, and the ability to filter information appropriately to avoid information overload. These requirements may in turn depend on other lower level factors. All of these lower levels could be analysed, and the combination of these different levels could be used to develop an overall picture of the viability of the concept. Performing these different levels of analysis will require a significant investment of resources, in terms of development of appropriate analytical techniques, and the performance of the analysis itself. It may be necessary to develop tools on an *ad hoc* basis, depending on the decision and the hypothesis, rather than relying on a suite of predefined methods.

64. An example of the way taking the decision perspective drives the resource requirement for analysis is the issue of robustness. For example, a positive decision on a new capability is unlikely unless it can be demonstrated to be flexible and robust. Analytic activities should then be directed towards testing a capability under a range of conditions. Experiments could be based on hypothetical situations, in order to stretch options and see where they break. For example, an NEO force structure may be hypothetically placed in situations where enemy jamming has disrupted friendly communications, or a wargame may include a Red Team fighting in an innovative way. Therefore, there may need to be a wide range of experiments for a single decision, adding to the resource requirements.

65. Finally, this approach creates the need for analysis to be embedded in the long-range planning process. Adopting the decision perspective mindset means that there is a requirement for analysis to be done at each of the above stages, so that the factors driving a possible decision can be broken down to the point where experimentation can be usefully applied.

66. A consequence of adopting the decision perspective is that the analysis performed will have greater chance of being considered useful, as it will be better directed, ie. focussed on

providing information that the decision-maker might require. It may also assist in raising the profile of strategic issues by explicitly linking them to current decisions.

67. The structured approach to analysis illustrated in Figure 2 makes no assumptions about the nature of the planning process: it is equally applicable to a variety of planning philosophies, such as top-down, bottom-up or resource-constrained. What will be different in these cases is the nature of the decision, and the means by which they are generated. A concept-led long-range planning process, however, will be an explicitly top down approach, and if it is to be integrated into the organisation, must interface with the bottom-up and resource-constrained processes that already exist, notably in Capability Systems.

68. This approach to analysis is, of course, no guarantee of success. There will still be resistances to OR being involved in Defence's planning, be it long-range or otherwise, some of which have been outlined in the previous section. Having the analysis done with a decision perspective though is vital to giving it any chance of survival.

## 6. Conclusions

69. This paper has discussed what OR aims to do: that is, use the intellectual rigour of the scientific method in support of decision-making. The scientific method follows a continuous cycle, using analysis to form hypotheses, testing hypotheses in experiments, and analysing experimental results to form new hypotheses. This cycle means that analysis should guide experimentation, rather than the current practice of performing experimentation not linked to clear questions. Ideally, experimentation should be incorporated into the methodology of doing analysis, rather than existing as a separate activity.

70. Analytical work done to aid any planning framework should take a decision perspective. Establishing a link to a possible decision focuses the analysis on producing information that the decision-makers might find useful, by forcing the analytical methodology to adjust itself to the decision-maker's perspective. It also allows analysis to be done for any decision that needs to be informed, meaning that it is possible to embed analysis in the planning process. We would argue that embedding rigorous analysis and a culture of open debate in the process is important, as it creates an environment in which novel and innovative solutions to problems can be discussed in a way that helps lead to organisational improvements. In long-range planning, this could help the debate regarding new concepts. Embedding analysis will also be required for the decision perspective as analysis will need to be done at each level from splitting the decision into its key arguments, through to actually performing experiments.

71. There are several decisions to be made regarding the role of analysis in long-range planning, including among other things the independence of the analysts. Those issues will all have some influence on the value that OR can add to the planning process, both in

terms of quality of work, and value to the decision maker. One consideration that will need to be dealt with if analysis is to be included in the framework at all is that of resources. Producing good analysis and running a useful program of experimentation requires people and dollars, and for long-range planning, a commitment over a long time.

72. There are elements of organisational culture within Defence and the analytical community that currently mitigate against getting full value from analysis. It is clear from Figure 1 and the comment from LTGEN Mueller that senior executives currently see little point in using the results of OR as it is currently practised to inform their deliberations. It also appears that long-range decisions receive less attention than immediate resource decisions, a situation that has implications for a long-range planning framework in its entirety. However, OR has the potential to contribute significantly if incorporated appropriately into the long-range planning process, and if it can demonstrate its utility may be a catalyst for changes in the decision-making culture.

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19. ABSTRACT  Head Policy, Guidance and Analysis (HPGA) seeks to develop a strategic planning framework to better support Defence decision-making. This paper was written in response to HPGA's request for advice on the potential role of Operations Research (OR) and analysis in such a framework. A broad interpretation of OR is proposed that includes qualitative analysis of problems that are not amenable to the quantitative methods with which OR is more traditionally associated. Cultural and ownership issues that must be addressed if OR is to be successfully incorporated into Defence's decision-making processes are discussed. It is argued that OR and analysis should be conducted with a decision perspective, and that analysis should be embedded in all aspects of a strategic planning framework. Working definitions of terms and concepts are presented to provide a common lexicon for those involved in the development of long-range planning.			

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